5D Chess Notation Standard Proposal

AquaBaby From the discord

Editing and help by Kittlish

A special thanks to all those that helped in the process of theory crafting and editing this paper, Including but not limited to: AverageHuman, Kittlish, PseudoAbstractMeta, Shad Amethyst, Plague,

Abstract

This paper serves as a theory of how notations should be created, and then goes into detail about notations that have been created by other members of the community. The paper then proposes a new possible standard of a new notation system that is easy to use and understand. The main goals of the notation system are ease of use and human readability. The paper ends on several examples of the notation in use. The overall goal of this paper is not to prescribe the proposed notation. The goal is to critically look at all of the notations and summarize the properties of each to the reader so that they may weigh the differences and decide which one they like the best.

1 Introduction

Since the game "5D Chess with Multiverse Time Travel" was released 3 months ago, several notation systems have been developed. Notation is the way that games are documented and have been important to the growth of board games such as chess, which has a (mostly) consistent notation system called Standard Algebraic Notation (SAN). This paper assumes that the reader understands SAN, and all of the basics of 5D chess.

Most readers will simply want to read the sections 7.Rules, 8.Examples, and the side by side comparison of notations. The other sections contain theory and other documentation that is needed for discussion, but not for comprehension of the proposed notation. All content of this paper is open to discussion, and not finalized as of now. This paper also features a TLDR summary, Which quickly covers the theory contained in the paper and my personal ratings of other notation systems. The rules are omitted from the TLDR, as I feel they should be as concise as possible where they are stated.

2 Terminology

Some of the terminology that is here is taken from the discord and/or Shad Amethyst's GitHub link https://github.com/adri326/5dchess-notation/. Other terms are either common in discussions

or are taken from the documentation of other notations. Shad Amethyst's terminology was particularly helpful here. More terminology at: this link

2DChess: Two dimensional chess, *i.e.* Traditional Chess

5DChess: Five Dimensional Chess, with time and multiverse dimensions added. This term is actually a misnomer, as there are technically only 4 usable dimensions.

Action: see 'Turn'

Active Board/Timeline: Active timelines are timelines that may influence the present. An active board is the playable board on an active timeline. A players nth created timeline is considered active if the opponent has created n-1 timelines. All Active timelines resting on the present must be played on in order to advance the present.

Advancement: Advancement of a board, moves the playable board on that timeline one sub step and flips the color of the playable board. Advancement also locks in the previous sub step as a history board. Advancement of the present moves the present forward by one sub step.

Board: a two-dimensional state of a chess board. While 2D chess takes place on one, mutable board, boards in 5D chess are immutable. Boards cannot be changed, instead any move made creates a new board.

Branching Move: A move where a piece moves from a Playable board to a History board, thus creating a new timeline.

Check: If a timeline's advancement allows the opponent to attack any of the moving player's kings, that timeline is in check.

Checkmate: If a player is in check and has no legal moves, they are in checkmate.

Future Timeline: A timeline that is further ahead in time than the present.

History Board: A board where a move has already been played. Some call this a past board, however that can be a misnomer with the existence of a shifting present.

Inactive Timeline: A timeline is inactive if it does not affect the advancement of the present in any way. This is opposed to a future timeline which may affect the present when it catches up. An inactive timeline cannot move the present at all. Inactive timelines will either be colored white or black, unlike active timelines which are colored purple.

Jump: A move which transports a piece outside its origin board.

Jumping Move: See 'Temporal Move'

Legal Move: A move that does not leave the moving player's king in check.

Layer: The full space contained within a particular L coordinate. Any layer can only contain at most one timeline, but the layer spans fully across time even though the timeline may not.

Mandatory Move: A move that must be made in order to pass the turn.

Move: A movement of one piece**.**

Multiverse: A group of timelines.

Rewinding the Present: The act of shifting the present backwards in time.

Optional Move: A move that did not need to be made in order to pass the turn, i.e. moving on a board further in the future than the present, or moving on an inactive board.

PGN: Portable Game Notation – a standard plaintext format for recording chess games.

PGN5: My proposed file extension for recording 5D chess games.

Playable Board: The most recent board in a specific timeline; as opposed to a history board. Note this is not the same thing as an "Active board".

Present: Defined as the time of the earliest active board/timeline.

Softmate: A version of check where the only legal moves involve rewinding the present.

Spatial Dimensions: 2D chess dimensions consisting of a rank(x) and file(y)

Spatial Move: A move where a piece's origin and destination is on the same board.

StaleMate: When the moving player cannot make a set of legal moves to shift the present.

Step: The base unit of time in 5D chess, representing turns passing within a game of 2D chess. For example T1 is 2 steps away from T3. A step consists of 2 sub-steps which are each boards of different color at the same time.

Temporal Dimensions: Dimensions that exist in time, consisting of Steps(T) and Timelines(L)

Temporal Move: A move where a piece moves from one playable board to another.

Timeline: a collection of boards that make a contiguous universe or line of play. The game begins with one or more timelines, and new timelines are created when a jump's destination is a history board, aka when a branching move is made.

Turn: a set of legal moves that allows the player to press the submit moves button and pass play to the opponent. A turn must change the location of the present, either by advancing the present or by rewinding the present.

Turn$_2$: A unit of time – see step. Some players refer to units of time in this way, however for the sake of this paper Turn will only refer to the first definition. "Turn" may also refer to a

coordinate in time, but to again avoid confusion this paper will always refer to the coordinates with T.

Unplayable Board: See History Board.

3 Goals

There are several goals that can be focused on when making a notation. Different goals will create different types of notation. Additionally, certain goals are subjective (such as human readability) which will create a difference in preference between notations.

3.1 Human Readability

The main aspect of Human readability is visual clarity of notation. This includes not only the use of symbols and characters to aid readability, but also the use of objects such as delimiters and white space. Additionally, human readability can include certain markers to make it easier to understand what is happening in the game. For instance, the '+' check symbol in 2D chess notation is not necessary, however it aids in players' understanding of the game.

For example, in plague's notation placeholders are denoted as --, which lacks visual clarity. An example move "6w Qf3 -- -- -- -- --" is slightly harder to tell how many timeline placeholders there are at a glance than the proposed notation of "Qf3 ^ ^ ^ ^ ^" . Another example is coordinates. In AN a coordinate is "**L0T6f3",** whereas in the proposed notation a coordinate is **"[0LT6]f3"**. The proposed notation breaks up the coordinate for visual clarity.

3.2 Ease of Use

Ease of use falls into two categories: verbosity and simplicity of rules. Verbosity is defined as the amount of characters that are needed to convey an idea. Lower verbosity is better for ease of use because files will be smaller, and human annotators will take less time writing down their moves. Lower verbosity can conflict sometimes with the goal of human readability. Simplicity of rules has to do with how many rules a notator must remember in order to notate a game.

3.3 Machine Readability

The ability for a machine to parse written notation is not a foremost concern, however, it may be important for certain projects, such as if a notation system is intended to be written and read by a computer program. It would be nice for extensibility to make our notation easily read by computers, but this is not a concern as any notation that fits all of the other categories will always be machine readable.

3.4 Clarity

As a final note, any notation system must leave no room for ambiguity. This impacts some of the above categories, but it is obvious why there cannot be any ambiguity within notation as a slightly different move will change the course of a game.

4 Other Notations

For a Side by side comparison of all notations, see [this google sheets page]

As mentioned above, there have been several attempts already to develop notation for 5D chess. The ones I am aware of have been listed here, and knowledge of each of these notation systems has contributed in some way to the creation of this proposal.

4.1 Overview Of notations

Notation Name	Pros	Cons	My Personal Rating
Shad's Notation	Clean, Machine Readable. Has examples, good documentation	Too many symbols, a little too verbose. Some explicit rules seem to be missing.	8/10
Axels Algebraic Notation(AN)	Least Verbosity, good documentation	Throws away Readability for the sake of lowering verbosity.	7.5/10
RAN	Good raw format, contains much of the information needed.	Very verbose for human readable/ usable notation	7/10
Hexicube's Notation	A tweak of AN, for his Game viewer. In my opinion, an improvement on AN	little documentation but a few examples on it.	8/10
Matrix Notation	Visual, can hold game states. Unique.	Unclear when a move happened. Possible to reconstruct games wrong.	7/10
Nidlatam's Notation	Interesting Ideas put forth by this notation	Too little examples, too verbose to be a	5/10

		notation.	
Alexbay's Notation	Good raw format. can be used with his viewer to load and save games.	Not very readable, lacks accessible documentation	
AverageHumans Notation	Based off of RAN, with certain tweaks. Simple to understand/ simple rules. Less verbose than RAN	Doesn't do anything particularly well. Seems too verbose for a human format and too implicit for a raw format.	5/10
MAN			
Proposed Notation	Based on predecessors. with a goal of readability and verbosity.	a bit more verbose than others, but overall well rounded. Probably cannot be easily parsed however.	8/10

4.2 Shad's 5D chess algebraic notation

link: https://github.com/adri326/5dchess-notation/

Shad's notation is meant to work with his engine, which means machine readability was a primary concern when creating the notation. The examples of this notation contain a header which mimics PGN.

The symbols that are used in this notation are + for check * for softmate # for checkmate > for a temporal move >> for a branching move, and ~ for a move that rewinds the present. the symbol x is also used to denote a capture of a piece for all types of moves.

In all of the examples listed at the above link, moves are listed by layer ascending for black and descending for white. This is not an explicit rule however.

aside from this, turns are separated with /.

```
[White "Teln0"]
[Black "Shad Amethyst"]
[Board "Simple - No Queens"]
[Size "7x7"]
[Date "2020.08.14"]
[Result "1-0"]
[Mode "5D"]

1. (0T1)Nd3 / (0T1)Nc5
2. (0T2)Nxc5+ / (0T2)bxc5
3. (0T3)g3 / (0T3)g4
4. (0T4)Bg2 / (0T4)d5
5. (0T5)O-O {to the right} / (0T5)Be5
6. (0T6)Nb1>>(0T5)b3 / (1T5)Bb6
7. (1T6)Nc3 / (0T6)Ne7>(1T6)e5
8. (0T7)a4 (1T7)O-O {to the right} / (0T7)Be5>>(0T6)e4
9. (-1T7)Bxe4 / (-1T7)dxe4 (1T7)c4
10. (1T8)Nb3>(0T8)d3 (-1T8)a4 / (-1T8)Bd4 (0T8)Kd7>(1T8)d6
11. (-1T9)Ra3 (0T9)Ra3 (1T9)b3 / (-1T9)Bd4>x(0T9)d3 (1T9)cxb3
12. (-1T10)d3 (0T10)cxd3 (1T10)Ba3 / (-1T10)Nd5 (0T10)Rb7 (1T10)c5?
13. (-1T11)dxe4 (0T11)Rc3 (1T11)axb3 / (0T11)Rg5 (1T11)Ne5>x(-1T11)e4
14. (-1T12)Rd3 (0T12)d4 (1T12)b4 / (-1T12)c4 (0T12)c4 (1T12)cxb4
15. (-1T13)Rd4 (0T13)d3 (1T13)Ba4+ / (-1T13)O-O-O {to the left} (0T13)cxd
16. (-1T14)Rxe4 (0T14)exd3 (1T14)Bxc5+ / (0T14)Bg2 (-1T14)Nd5>x(1T14)c5
17. (-1T15)Rc4 (0T15)Rc6 (1T15)Ra5 / (-1T15)e5 (0T15)Bd3+ (1T15)Ne4
18. (-1T16)Rb4+ (0T16)Kg1 (1T16)Nxe4 / (-1T16)Kb7>x(0T16)c6 (1T16)dxe4
19. (-1T17)Rb4>(1T17)b4 (0T17)Bxg5 / (-1T17)Bc4 (0T17)Bc4 (1T17)Nd5
20. (-1T18)Be3 (0T18)Rc1 (1T18)Rd4 / (-1T18)Rd7 (0T18)Kc6>(1T18)b6?
21. (-1T19)Bb6+ {checks (1T19)d6} (0T19)Rb1 (1T19)Raxd5+ / (-1T19)c6>(0T1
22. (-1T20)Bb6>x(0T20)b7+ {checks (1T20)d7} (1T20)Rxd5+ / (-1T20)Bc4>>x(-
23. (-2T19)Bb6 / (-2T19)Rb7
24. (-2T20)Bb6>>x(-1T20)a6+ {checks (1T20)b6, (2T20)b6 also checks (1T19)
```

In my opinion this notation is extremely clean and clear. Since it is so verbose, it avoids a lot of edge cases that may be problems in other notations. This notation is definitely my #2 favorite and a gatekeeper/ benchmark for which to compare other notations. My only complaint is the notation does not bring up the problem of order mattering when branching multiple times in one turn.

4.3 Axels Algebraic Notation

link:
https://docs.google.com/document/d/1G456NzkPc_ZsAj3HBpdTZuTP3tP-g1k98GdoRE38E5A/view

Axels notation is another strong notation that has been created, and mainly as a human readable format. While the paper discusses both Reverse Algebraic Notation(RAN) and Algebraic Notation (AN), only AN will be discussed here as RAN was made for purely documentary and explanatory purposes. One major aspect of RAN however is the use of a turn prefix. For instance, before a set of moves, the notation states: whose move it is, turn number, and time of present. While all of those are implicit in other notations, they may be included to improve readability. RAN also uses full origin and destination coordinates for all moves. For example, **L0T6Nf3 xP L0T6e5** is a movement of a knight taking a pawn. You will notice the example is a spatial move, and much of the information is redundant. Branching moves: **L0T6 Ng1 L0T5g3 (+L3)** also denotes the Timeline that was created. AN makes much of RAN optional.much of the turn prefix except for turn number is optional. time of origin is also optional, since a playable board has a definite time. If the origin timeline is omitted, it is assumed that the timeline is +1 or -1 of the previous moves origin timeline depending on if the moves are in ascending or descending order. The notation mixes the order, and dictates that you should put whites moves in ascending order and blacks moves in descending order.

3. Additional info

Useful additional info can be added much like for 2D chess. Worthy of mention are forcing moves, for which we can be a bit fancier:

- + : check to an active King
- * : check to a history King (one which cannot move)
- * + : check an active King and a history King
- ++ checkmate on a board (check from a board and no single move from that board to itself can save you)
- +* stalemate on a board (no legal move from that board to itself)
- # global checkmate

Preferably, a check should be signaled after the move that triggers it,after the board (timeline and time) when the threatening piece is at.

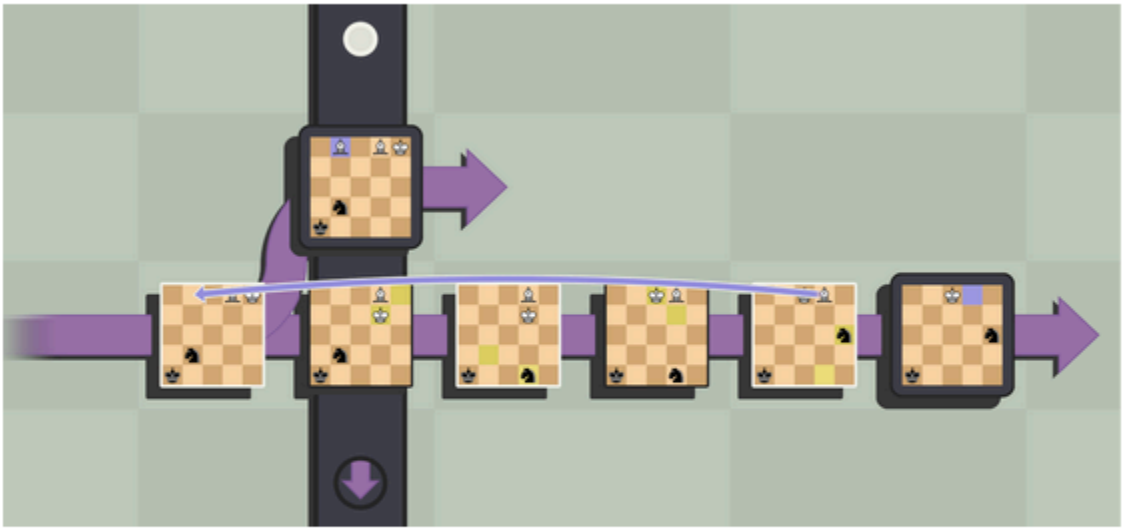
A 'p' following a newly created timeline can be used to indicate that it is passive.

are the symbols used in the notation, both AN and RAN. semicolons are used to separate moves on the same turn, and / are used to separate turns. I couldn't seem to find any long examples of this notation being used, perhaps I will Notate game with this notation.

One thing I find confusing about this notation is the use writing moves on subsequent timelines. While the proposed notation does the same and is shown below, there seems to be a lack of readability 1. L+1N L-1a2 *; b3 # This is one example that is given , but I'm not sure how I would notate Figure 1 or 2 Perhaps they would be notated as: **L+2Q L-2d5 ; L+1N L-1e4** for figure 1. One thing I will say is that since there are no characters breaking up the coordinates, they are a bit harder to read. Additionally, I can not find if the notation mentions the fact that

branching matters within it, which is an important edge case. Overall AN is very strong and a worthy standard. It is probably the least verbose option,however it suffers somewhat in readability. A last example is Knight Tactic 8

6. Knight tactic VII



- AN :

1T3.L0N L-1T1* #
Pure time travel, no need to give space coordinates.

The fact that no spatial coordinates are given is fine, however makes the file much less readable to a human. They will need to look at the prior turn to know where the knight was.

According to Shad Amethyst:

> *I commented on this a while ago while chatting with Axel, who told me that indeed, this notation usually requires a screenshot to be attached with it and is designed with that use case in mind.*

4.4 Hexicube's Notation

link: https://github.com/Hexicube/5D-Chess-Game-Viewer

Doc:
https://www.google.com/url?q=https://docs.google.com/document/d/1IdOVqk8a16t06RcM9rIqK11SSxPCu4kZ70CkfC-T00A/&sa=D&source=editors&ust=1619994412126000&usg=AFQjCNEczd_qBzedyg_zQebjbMNZM_ky8Q

```
1. c4 .. e6
2. Nf3 .. Nc6
3. g3 .. Nb4
```

```
4. Qb3 .. h5
5. Bg2 .. Qe7
6. O-O .. Na6
7. d4 .. Nf6
8. Ne5 .. Ne4
9. Bxe4 .. h4
10. g4 .. Qg5
11. Bxg5 .. Bd6
12. f4 .. L0d6 Bx T10d4
13. Nf3; - .. Be3
14. Bxe3; - .. Rh6
15. L0e5 Nx L-1e7 .. Bxe7; O-O
16. Bxh6; f5 .. Bf8; exf
17. Bxb7; Bxf5 .. Bd6; Re8
18. Bxc8; Bd8  .. Rxc8; Rxd8
19. Bxg7; Qe3
```

Hexicube's notation is used in his game viewer. The notation uses ; to separate moves, and .. to separate turns. I couldn't find documentation on this notation, but it seems like for spatial moves, the timeline is implicit, and if a timeline has a history board lined up with the present, a – is used. Since there seem to be many edge cases and not very much documentation, I can't provide much further comment. It is an improvement in terms of reducing verbosity, but otherwise feels lacking.

4.5 Matrix Notation

link: https://drive.google.com/drive/folders/10332r6crq_pD-d4pG4VSynM8ziu1uT98

Matrix notation has a more unique approach, because it uses a spreadsheet format. This mimics the actual game to a degree, since columns in this notation are timelines and rows are time. Therefore, no origin temporal coordinates ever have to be supplied, and instead the notation focuses on where something happened. The issue with this notation is that it does not provide information on turn order or when a move is not played in the present. This can cause issues when trying to explain the 10th move. For instance, if on my 10th turn, I rewind the present to T3 and then make a move on +1L, it's hard to know just by looking at the sheet that the +1LT4 move happens on my 11th turn. Another issue with the notation is it is ambiguous when a player makes a non-present move, thus certain points in the middle of the game will need to be described by the annotator to remove potential ambiguity. Also, it is impossible to visualise the notation without spreadsheet software or by taking a screenshot, which limits its utility. However, the effort that has been put into making this notation and annotating several games with it is appreciated.

			(e3,c5)		
			(c3, Qb6)		
			(Na3, h5)		
		(+R{O.T14}.b1, Qf6)	(Nc4, Qf6)		
		(b4, e6)	(Nf3, Nc6)		
		(bxc5, Bxc5)	(Na3, a6)		
		(Nf3, a6)	(h4, d5)		
		(d4, Bd6)	(Rh3, e5)		
(+Q{WH2.T11.b6}.b6, Bd6)		(Bb5, Nc6)	(Nb5, axb5)		
(Qa4, Ne7)	(+Q{WH1.T15.b6}.b6, Qd8)	(Bxc6, bxc6)	(Bxb5, e4)	(..., +Q{O.T14.f6}.xf2)	
(Qxc6, +B{WH2.d6}.xc6)	(-Q.O.T9.b6, -B.WH3.c6)	(-N.BL1.f2, Ne7)	(Ng5, Bxh3)	(+N{WH1.f3}.xf2, e4)	
(Be2, 0-0)	(e4, Ne7)	(Qb3, 0-0)	(Nxh3, Bd6)	(Nxe4, dxe4)	(..., +Q{WH1.T14.h4}.xf2)
		(Rf1, Qh4)	(Rb1, Ne7)	(Qb3, Bd6)	0-1
		(Qb6, -Q.T12.f2)	(-R.T4, @)	(Bxc6, @)	
			(..., -Q.T10.f2)		
		(-Q.T10.b6, @)			

1. 2(-N{c3}.T2.d3) 1(+N{T2.c3}.d3)
2. 1(-N{WH1.c6}.O.T1.e6) 1(+N{WH1}.e6)
3. 1(-N{c6}.WH1.b6) 1(+N{BL1}.b6)
4. 1(-B{BL1.c4}.WH1.e4) 1(+B{BL1}.e4)

There is a version of this notation that does not use spreadsheets, however it can be very hard to read. It also seems redundant (and confusing) to have a move notation that contains both the departure and the arrival, as notated on the first line of the above example.

4.6 Nidlatam's Notation

link: https://github.com/nidlatam/my-5d-chess-notation/blob/master/notation/notation

There is currently only one example of this notation, which makes it hard to understand. Coordinates are described in his notation as xy|T||L| *i.e.* a1|10||#2| would be a1 T10 layer 2, whited out(?). The one example move given is +D a1|20||0| -#2-> -B a2|19||1|.

Which I assume means a white dragon at [0LT20]a1 captures a black bishop, two orthogonal units away at [+1LT19]a2 ?

Moves need to be ordered by their source timeline index, no matter what. This means that a specific order of branching moves can possibly not be denoted. One interesting thing about that,

however, is that timelines that receive a jumping piece need to denote the branch from which that piece is coming from.

> *ok there are things I forgot to add.*
>
> *first of all*
>
> *there are times where you get a checkmate not because the check can't be stopped. But because if you do stop it, you won't be able to move on the other board.*
>
> *Normally someone like Shad would say something like*
>
> *"This is the defenition of checkmate".*
>
> *But this is my notation so I do not care.*
>
> *If this happens you put in the end*
>
> *--stale-checkmate instead of --checkmate*

My favorite Part of the whole document; Made me chuckle

4.7 Alexbay's Notation

Link:https://chessin5d.net/#/ and https://gitlab.com/alexbay218/5dcwmdtt-tool/activity

```
1w. 1:Ng1:f3
1b. 1:Ng8:f6
2w. 2:Nb1<+1>1:b3
2b. 1+1:Ng8<-1>+0:g6
3w. 2-1:Nf3:d4
3w. 2+1:Ng1:h3
3b. 2-1:Ng6:e5
3b. 2+1:g7:g6
3b. 2:Nb8:c6
4w. 3:d2:d3
4w. 3-1:d2:d3
4w. 3+1:e2:e3
4b. 3-1:Ne5:xd3
4b. 3+1:Nb8:c6
4b. 3:b7:b6
5w. 4-1:Qd1:xd3
5w. 4+1:Qd1:h5
5w. 4:Nf3:e5
5b. 4-1:Nb8:c6
5b. 4+1:b7:b6
5b. 4:Bc8:b7
6w. 5-1:Qd3:f5
6w. 5+1:Nh3:f4
6w. 5:Ne5:xc6
6b. 5-1:Nc6:e5
6b. 5+1:Nc6:d4
6b. 5:Bb7:xc6
7w. 6-1:Qf5:xf7
7w. 6+1:Nf4:xg6
7w. 6:Bc1:e3
```

4.8 AverageHumans's Notation

link: https://pastebin.com/EwVSTFbj

4.9 Tesseract's Notation

Link:https://github.com/penteract/cwmtt/blob/master/notation.md

Tesseract's notation is in many ways similar to shad's notation, but less verbose. I would describe it as a hybrid shad/hexicube notation.

4.10 Multiuniversal Algebraic Notation (MAN)

link:

https://docs.google.com/document/d/1d1tBjl--rIXTEF6KM_81QMzAVgpe1m33ovCSoO7XGMc/edit

This notation is heavily based on Kittlish's notation and discussions about it had in the official 5D chess Discord server.

5 Ideas For syntax/lessons learned.

5.1 Shortcuts.

Shortcuts are ideas that allow us to cut down on the verbosity of the notation by removing implicit information.

Origin time can always be removed. This is because the origin of a move, as long as we know the timeline, has to be the playable board of that timeline. There is only one playable board in a timeline, to time is implicit.

Origin spatial square can be removed from non ambiguous moves similar to chess. For instance you could simply write Nf3 and not g1Nf3 or something similar containing origin. If multiple of the same piece can make the same destination of the move, specify rank, or file. for example Rae1 if both rooks can reach e1.

As discussed in 4xels AN, pure temporal moves can omit the destination spatial square. For instance, Knight Tactics VII.

As discussed in AN, Hexicubes AN, and others, origin Timeline can be omitted if some system is used to make it implicit. For example AN uses a system that states if two moves have adjacent origin timelines(ascending or descending depending on the color), some or all of those moves can omit the origin.

5.2 Convention Ideas

One idea which may have originated in Hexicube's notation, is the idea of placeholders. Placeholders are a way in which moves can have placeholders, which allows for notation systems to contain moves with implicit layers easier. One idea, which may have originated with this paper is the idea of different placeholders for timeline, void, etc.

Most notations use T and L next to the Time and Layer coordinate. This could be implicit for instance a coordinate system (x,y,t,l) however Explicitly stating a coordinate relates to a time or Layer makes it easier to read. An example of implicit coordinates is Alexbay's Notation.

Most notations use the convention of having SAN coordinates for the spatial coordinates.

5.3 Symbol Ideas

One idea which may have originated with Shad's notation is having a symbol to represent Temporal and branching moves. For instance, Shad's notation uses >> to signify a branching move. This is a good idea to flag the reader that a branch happened. Usually not many branches happen per game, and when they do they are important, so symbols to signify branching can be useful.

One idea is to use a different symbol for check, softmate, hardmate, checkmate. Since the plus sign is used in other parts of many notations some have opted to use the percentage sign '%' for check. also it may be good to signify spatial and temporal checks differently. Some notations have used asterisk '*' for softmate.

Some Notations split turns by a newline and some do by a delimiter. Shad's notation as well as tesseract's notation uses a '/' to delineate moves. Hexicube's AN, and AN delineate by two periods '..'.

6 Groundwork For new notation

6.1 Guidelines for new Notation

I will base my new notation off of several guidelines. First, I want my notation to be easy to understand: anyone with a basic understanding of both regular chess notation and 5D chess should also be able to understand this notation. The notation should also cover any edge cases, so as to not induce any ambiguity. The documentation should have plenty of examples for people to study the notation and quickly pick it up for notation and play.

This notation will focus on readability first, and second ease of use. This notation will not focus on machine readability.

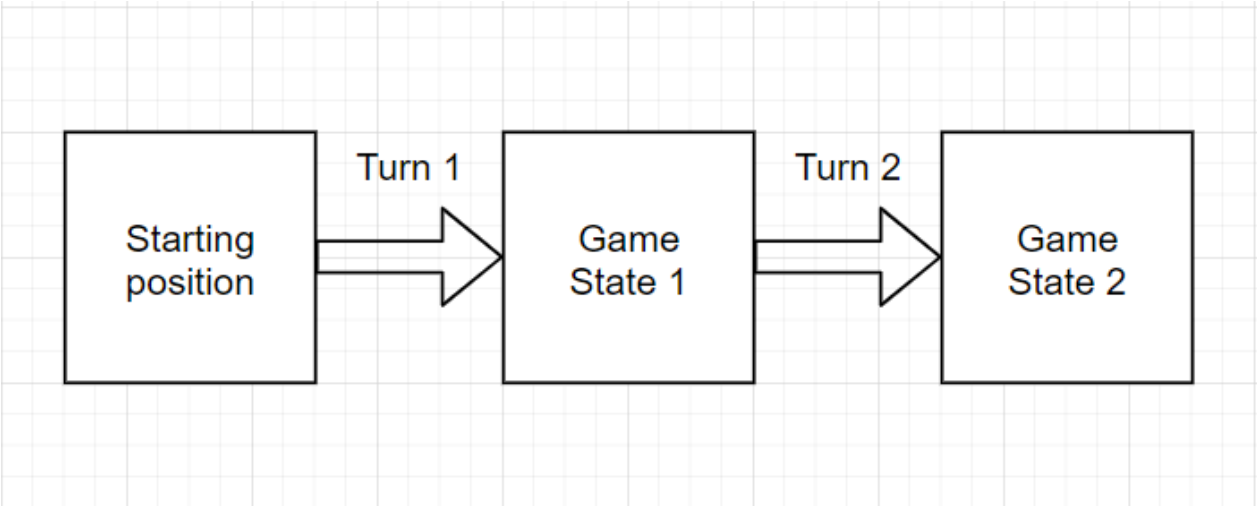
Lastly, the notation should aim to make sure that a single move has only one valid way of writing it. For instance in chess if two knights can go to a square, let's say e7, you must also denote a rank or file to eliminate ambiguity, like Nge7 if a knight went from g8 to e7. However, if there is only one knight that can go to e7, the move should be written as Ne7. Although Nge7 would still be clear in denoting what move was made, it may cause confusion. The rules must be strict so there are no “judgement calls" to be made during notation. In other words, there should not be multiple correct ways to notate a game.

6.2 Considerations

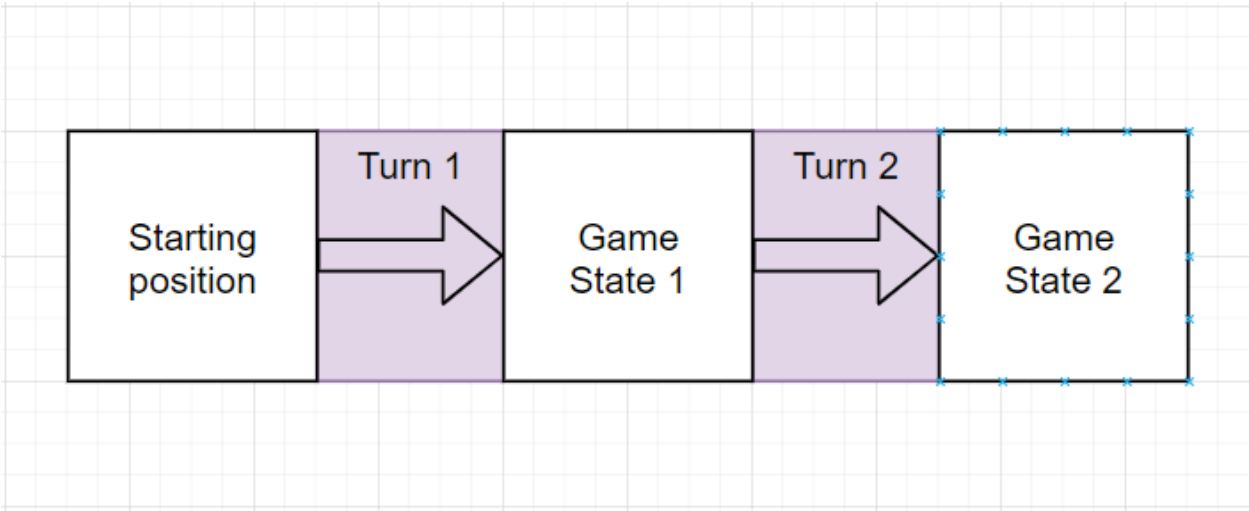
One consideration that needs to be made is the order of moves. In general, the order of moves within a turn does not matter. However, order matters when multiple branching moves are made in one turn. This is because whether a board lands on say +1L or +2L matters tremendously

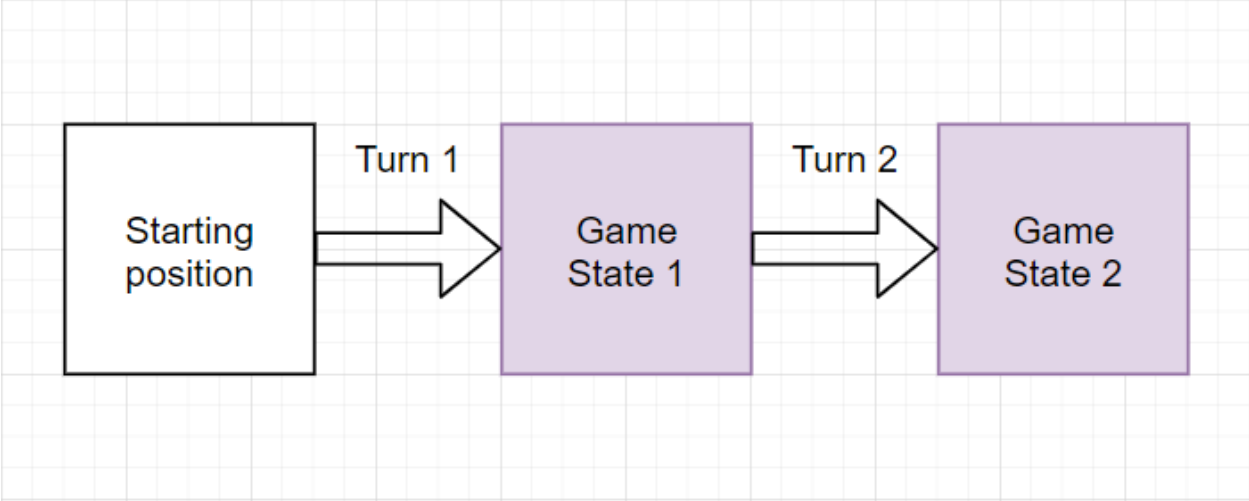
6.3 Notation theory(WIP)

Every game can be thought of as a series of turns or actions that lead to a series of game states.



The Strategy with saving a game can come in two ways, saving the information at each Game state or saving the information of each turn.





Saving the game state is impractical because it encompasses more data than the turn data. Each of the notation systems use what is considered incremental notation. this means to get to a specific game state, the prior turns must be followed and applied to the game. For this paper, only notation systems that are incremental are talked about. Game states could be saved for various purposes. For instance, puzzles could benefit from being loaded from a game state. A format like matrix notation could be used, since matrix notation isn't necessarily deterministic in creating a game, however it does denote a specific game state.

6.3.1 Vectors vs. Coordinates.

Because only changes are stored, an important decision can be made. Usually notations focus on moving a specific piece from one square to another square denoted by exact coordinate. For instance SAN uses specific coordinates for moves. *i.e.* Nf6. means a knight is going to the f6

square. However vectors can be used instead of coordinated. Use of a vector basically means supplying information on the piece's change of location rather than the absolute location that the piece landed on. For instance if a knight would go from a1 to b3, the knight would be moving right a square and up two squares. a vector move may denote the move as N(1,2) instead of Nb3.

while the 2d boards are finite, time and layers are not bounded, so they can be as large as needed in the game. vector notation may be an easier way to denote moves in this case. Vector notation may be harder to notate due to notates needing to count squares rather than looking at destinations.

6.3.2 Coordinates

This notation uses the coordinate system as follows:

$[c.xL.Ty.zw]$For the full coordinate, plus denotation of the color of the board.

$[xL.Ty.zw]$For the full coordinate

$[xL.zw]$ When the Board Time is implicit.

$zw$when both temporal coordinates are implicit.

where c is a color either 'w' for white and 'b' for black. x y and w are all integers, and z is the zth letter of the alphabet. The reason that z is a letter rather than a number is to both conform with 2D chess notation, and to differentiate the File from the Rank. For example a coordinate could be

[0L.T5.a4]

The brackets and periods are unnecessary, but are used for visual clarity. Specifying color is very optional and not very well used, since it is implicit. If its blacks turn for instance the move implicitly travels to a black board.

Vector notation may be used only for Time. Using Vector notation has been considered for use on layers as well, however since Layers can be negative there is larger room for ambiguity. to use Vector notation for Time, place the vector before the T rather than after, and make the T lowercase.

i.e [0L.-1t] is Layer 0, 1 time step back.

6.3.3 Game State Information.

There are several pieces of information that may not be a part of the turn or change in board state that may be given in the notation to help the reader. One idea brought up in RAN is to have a turn prefix. a turn prefix can give game state information before stating the moves on a turn. For our purposes there are several pieces of information that may be useful and they are as follows:

- The color of the turn
- The number of the turn
- The time of the present
- Number of white timelines
- Number of black timelines
- Number of active timelines.
- Number of playable boards for the color of the player playing
- number of inactive timelines
- number of first inactive timelines
- and so on

Any of this information could technically be in a notation if the author finds it appropriate to list said information. For the sake of the proposed notation, the authors only found it appropriate to list the first three points listed above in the turn prefix. all of the other information listed is simply implicit and while it may be nice, would make the notation too verbose.

6.3.4 Movement Information.

Movement information can consist of the following pieces of data:

- Origin coordinate
- Piece type moved
- Destination coordinate
- Vector of movement
- Piece captured
- result of movement (*i.e.* check, checkmate, softmate, capture, whether a branch was made)
- comments on the move. For example ! and ?? in SAN, although these are highly optional.

Certain more verbose formats such as RAN include most of this information. Notations such as AN seek to reduce verbosity by eliminating the implicit portions of the listed data. For instance, Portions of the origin and destination can be implicit and therefore removed. Piece captured, and result of movement, and comments are always unnecessary, and are mainly added to improve readability. The proposed notation seeks to strike a fine balance between removing unnecessary information and keeping a high level of readability.

@TODO remove this later.

The basics of incremental notation is that at each turn, the change in game state is documented. For 5D chess, a set of moves is documented. The most verbose way to annotate this would be to denote the origin coordinate, the piece, and the destination square. For instance, a move may include

e4 K e5

to denote a king moving from e4 to e5. A 5D move, having more coordinates may be denoted as $[0LT5]Bf5x[0LT2]f2$

in its most verbose mode. However, Time never needs to be stated in the origin coordinate. This is because in any given timeline, only one board is playable. Therefore

$[0L]Bf5x[0LT2]f2$

conveys all the information necessary to recreate the move.

It is recognized that denoting both a piece and full coordinates is redundant, since only one piece can occupy any given set of coordinates. While we could remove B to reduce verbosity, it would reduce readability which has been stated as the primary goal of this notation.

Different types of moves have different rules attached and as such should be notated slightly differently.

7 PGN5 Notation Rules

1. If there is only one timeline, the notation should be equivalent to SAN. *I.e.*

   1. e3 Nh6

   2. Bb5 c6
2. Otherwise, if there is more than one timeline, notate each Turn in the form:

   "(Turn Prefix)(Mandatory Moves)(Optional Moves)(Branching Moves)"

   Separate Turn Prefix and moves with a period and separate different moves with a comma and a space ‘, ‘.
3. The turn prefix consists of: The turn number, the color of the turn, and the time of the present at the start of the turn. The general form would be

   "(Turn number)(Color) T(Time of present)."

   Color is denoted as ‘w’ for white and ‘b’ for black. A valid turn Turn prefix would be:

   7w T5.
4. Mandatory moves and Optional moves are listed in order from low to high timeline and separated with commas. For instance, a move taking place on the -1L will be listed, Then the move on 0L, then the move on +1L and so on. Branching moves are listed in the order they occur.
5. Spatial moves are denoted as follows.

"[(Layer)L](Piece)(2DDestination)", or simply
"[(Layer)L](SAN)".
For example: **[0L]Nf3**. to disambiguate 2D origins, the same means as 2D chess are used *i.e.* **[0L]Nhg3**

6. Temporal Moves are denoted as follows:
"[(Layer)L](Piece)(2DOrigin)[(Layer)L](2DDestination)". For example
[0L]Ng1[-1L]g3
7. Branching Moves are denoted as either:
"[(Layer)L](Piece)(2DOrigin)[(Layer)L(VectorTime)T](2DDestination)". or
"[(Layer)L](Piece)(2DOrigin)[(Layer)LT(AbsoluteTime)](2DDestination)".
For example: **[0L]Bf5x[0LT2]f2** for coordinate notation or **[0L]Bf5x[0L-3T]f2** for vector notation. Branching moves must also be encased in angle brackets like so: ***<(move)>*** for visual clarity.
8. On each turn, each active timeline must have either a placeholder character or a move present.

- / denotes the timeline is the destination of a jump from another timeline
- ^ represents a history board at the active layer timeline
- v represents void in the active layer
- ~ represents a branching move in the layer.

Because all active timelines either have a placeholder or mandatory move associated with them, Omit origin Timeline from those mandatory moves since the timeline is implicit.

Figure 1 is notated as
/, /, Ne4, Nd4[-1L]e4, Qh5[-2L]d5
Figure 2 is notated as:
Qa5[+2L]e5, Nf3[+1L]f4, ^, /, /,

9. After mandatory moves, optional moves and branching moves are denoted. Optional moves also must follow the ascending order of timelines. Branching moves must be listed in the order that they occurred. All optional and branching moves must list Timeline.

10. Branching moves may rewind the present. In this case, the location of mandatory moves also changes. In this case, Mandatory moves are now equal to where the new present is. Figure 3 would be notated as:
    v, ^, ^, (move), <(Branching move)>
11. If a branching move is the only move made on a specific turn it is the only one listed.
12. If a move captures another piece, then add the symbol 'x' between the piece or origin coordinate (whichever comes later) and the destination coordinate, similar to SAN. For example **[0L]Bf5x[0L-3T]f2**
13. There are other symbols that are based off of the game state
    - If a move checks the opponent on that specific timeline, add the symbol % to the end of the move
    - If a move checkmates the opponent, add the symbol # to the end of the turn.
    - If a move softmates the opponent, add the symbol * to the end of the move.(optional)
    - If a move stalemates your opponent, add the = to the end of the turn
    - !, ? as per SAN.
14. Positive values associated with layer, and with Vector time notation must include a + sign for visual clarity. For instance **[+2L]** or **[0L+1T]**.

7.1 Justification of rules

7.2 Piece Symbols

Pieces use the same symbols as 2D chess, however there are a few new symbols. P is for princess, D is for dragon, U is for Unicorn. I'm not aware of any standard on brawn and royal queen notation, or some of the really newer pieces.

B: Bishop

*C: Commoner - Common King

D: Dragon

K: King

N: Knight

P:pawn (Reserved)

Q: Queen

*QQ: Royal Queen

R: Rook

*r: Brawn

*S: Princess

U: Unicorn

* Not standardized between notations.

7.3 Optional Rules/ versions

All symbols are up for discussion

Softmate symbols may be omitted, as new players may have a hard time detecting softmate. For example, if a player cannot find a legal move that advances the present, is it because none exist or the player simply cannot find one.

Regular chess notation may be omitted, as it does not keep consistency over the whole file. It is nice though to reduce space.

The / ^ v symbols may be condensed, and/or omitted however I like them because they explicitly tell where each timeline is.

7.4 Header

An example of a pgn header is as follows (straight from wikipedia):

```
[Event "F/S Return Match"]
[Site "Belgrade, Serbia JUG"]
[Date "1992.11.04"]
[Round "29"]
[White "Fischer, Robert J."]
[Black "Spassky, Boris V."]
[Result "1/2-1/2"]
```

As you can see the basic format is a section title, and the contents in quotation marks all encased in brackets. I simply propose that we keep all needed material, and add some things that are brought up in Shad's notation header. An example header for a casual/ random competitive game should look like:

```
[Date "2020.11.10"]
[White "AquaBaby”]
```

```
[Black "PseudoAbstractMeta"]
[Result "1-0"]
[Size "8x8"]
[Variant "Standard"]
[Time Control "20+5L"]
[Notation subType ”vector”]
[Notation “PGN5”]
```

The variant, Notation, and Notation subtype are all Required fields in the header.

The optional headers include:

- Naming each player, and the side they are playing
- The result of the match
- The time control of the match
- The date on which the match was played
- The size of the board(Implicit in the variation)
- Tournament Information, such as round number

8 Examples

8.1 Side by side Comparison

For a side by side comparison of notations, see this spreadsheet

Figures 1 and 2

Figure 1

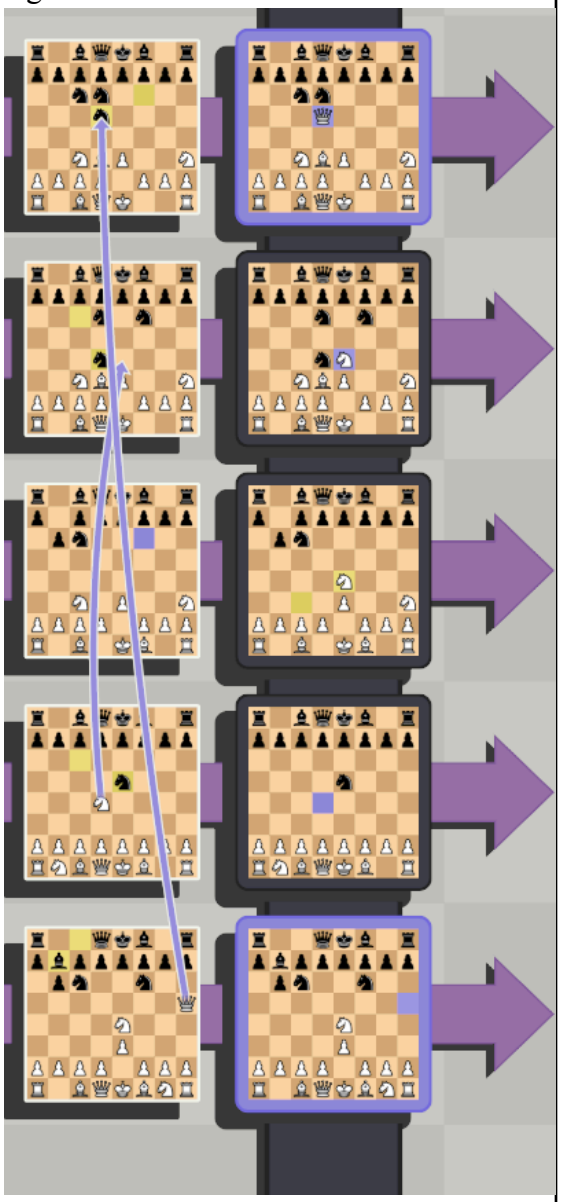


Figure 2

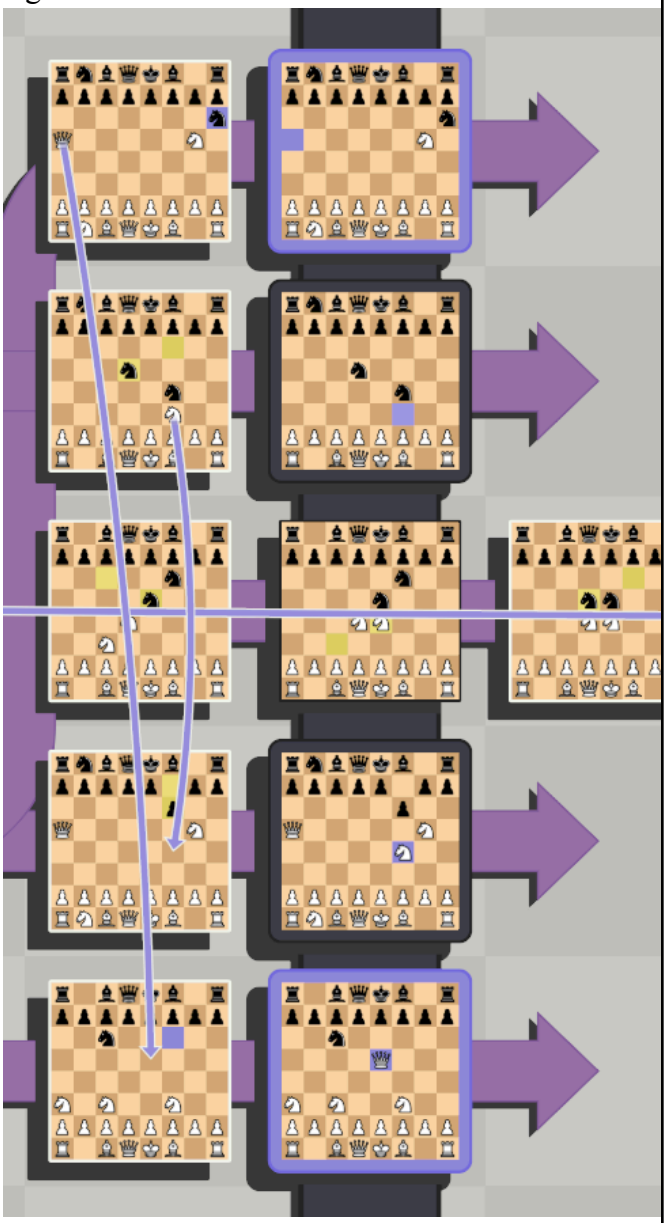
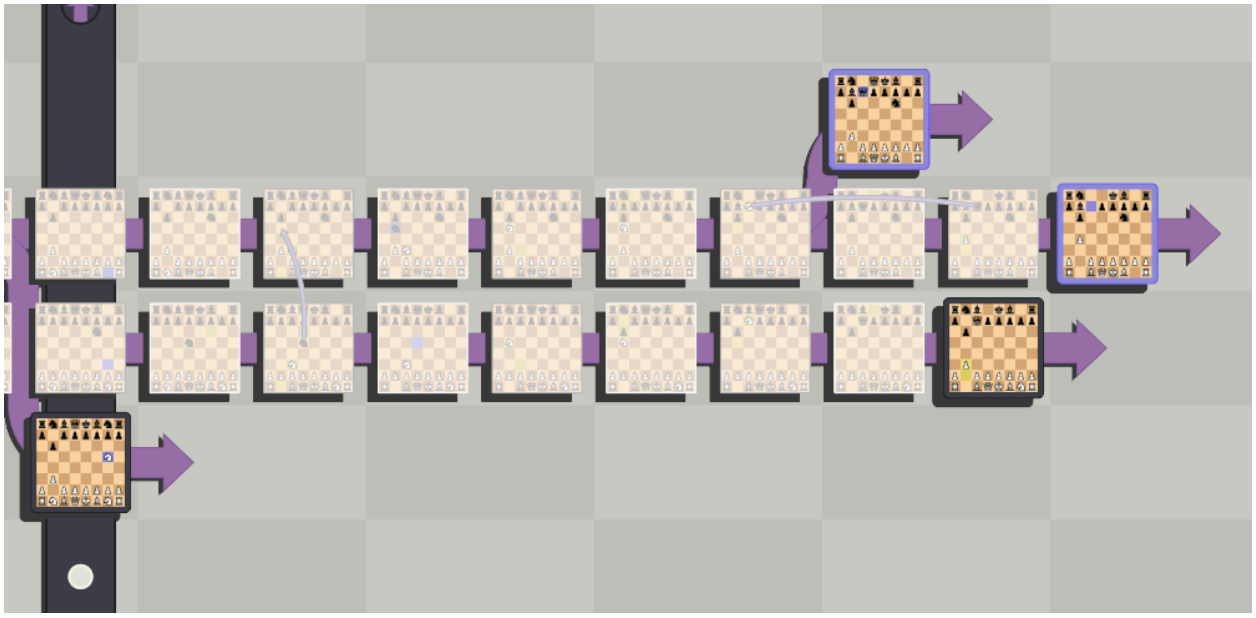
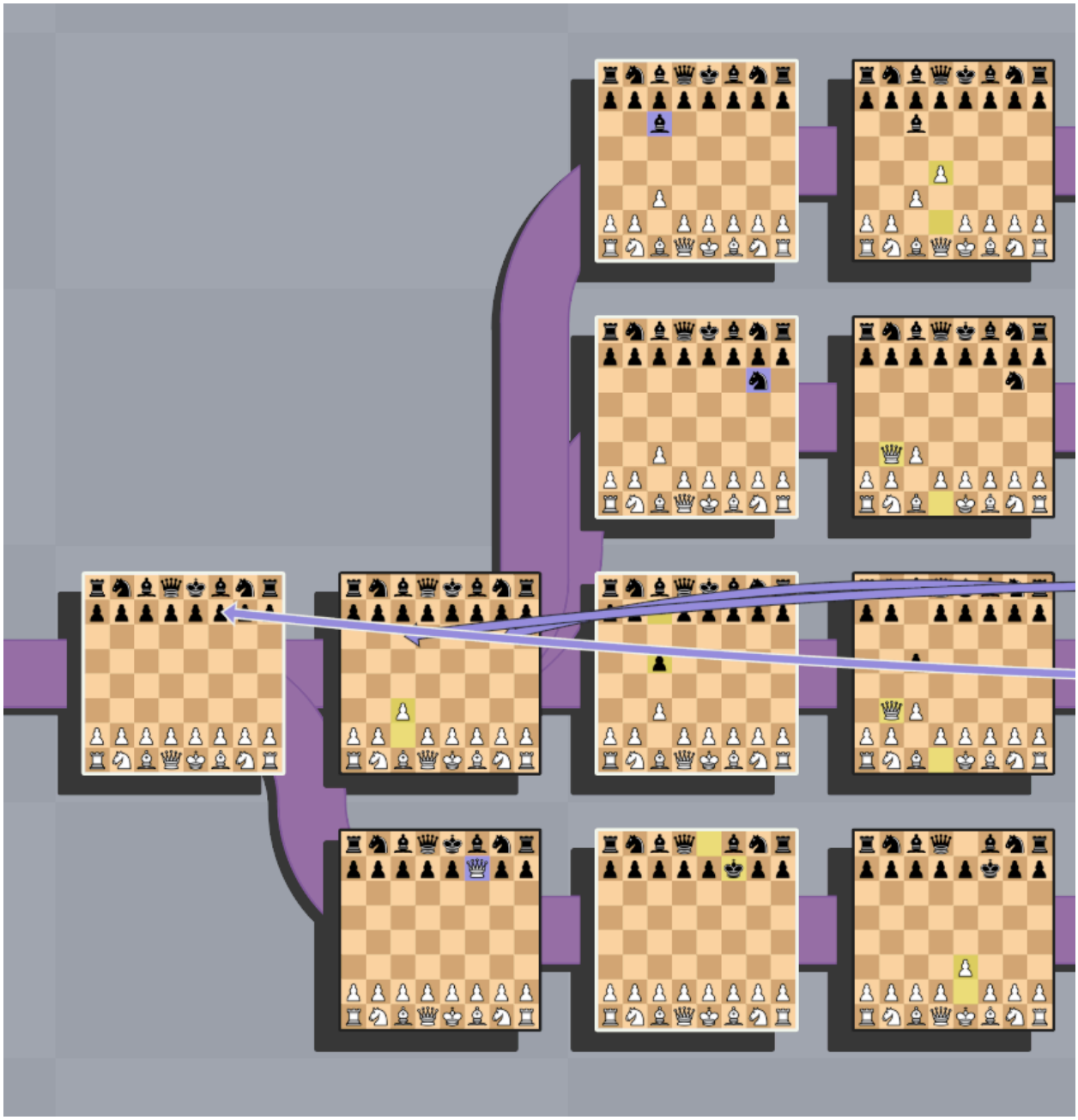
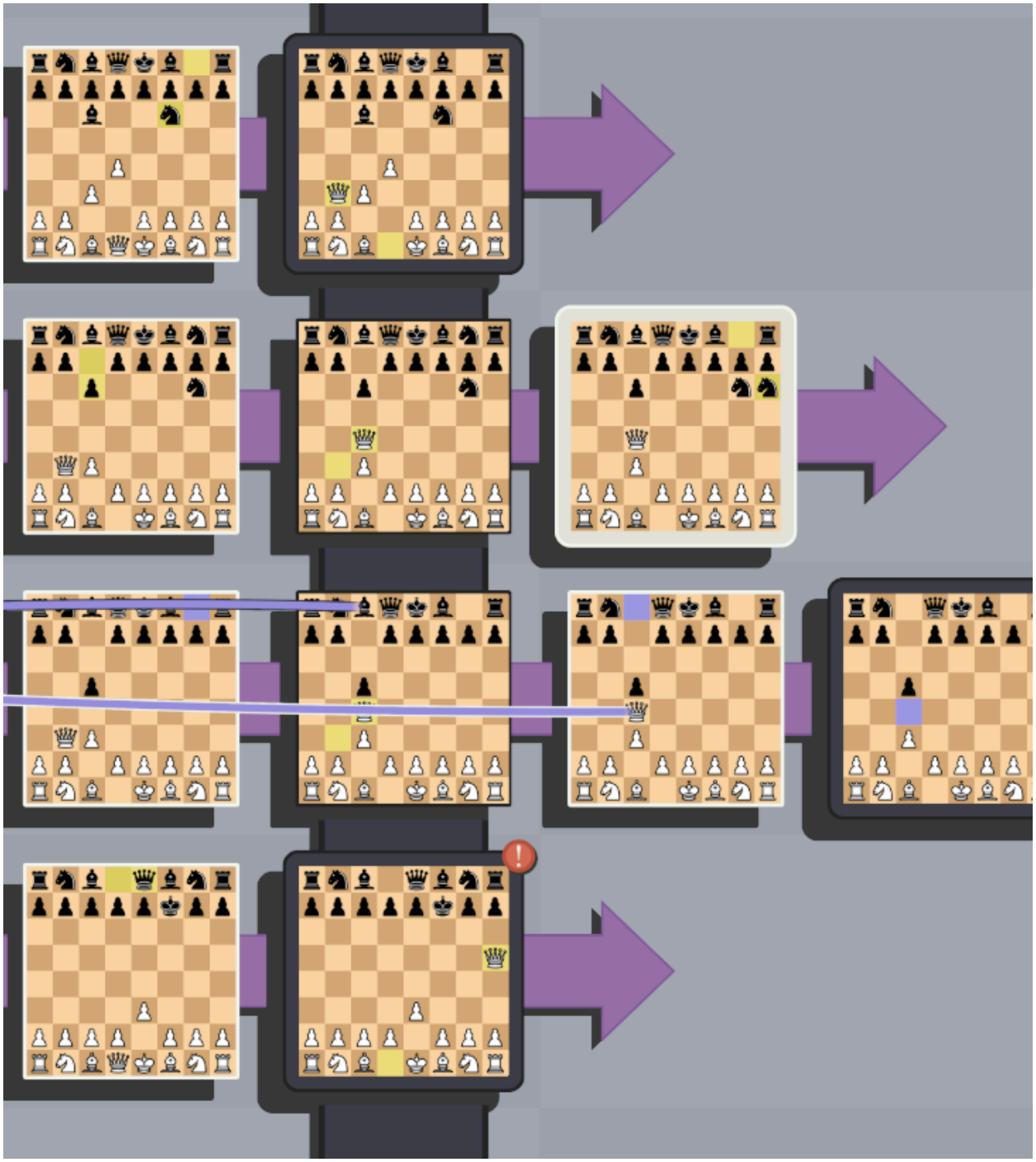
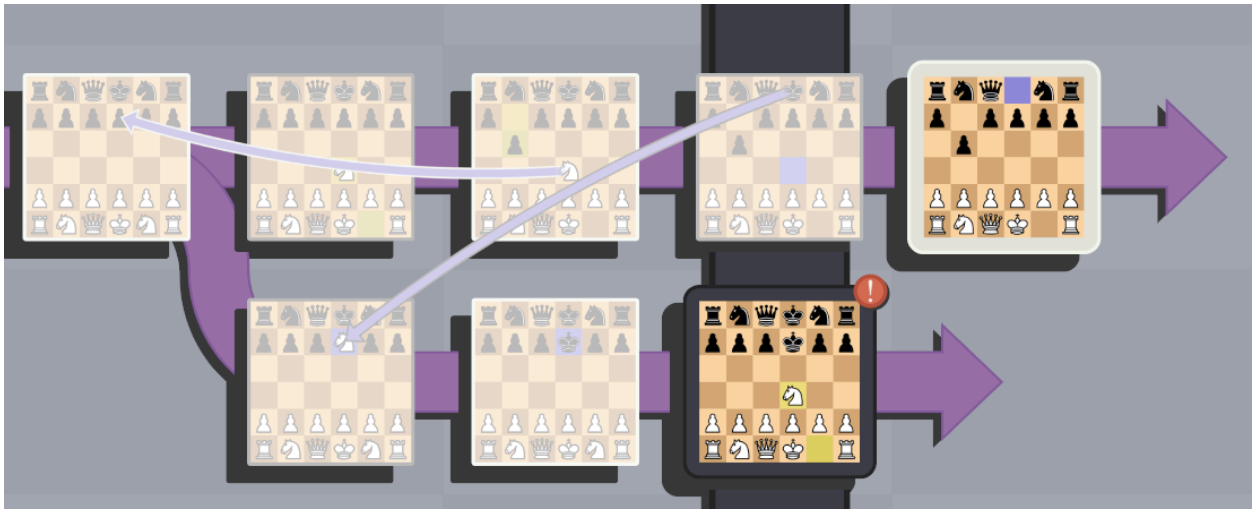


Figure 3:









```
[White "AquaBaby"]
[Black "Agressive AI"]
[Result 1-0]

1.Nd3 b4
2w.<[0L]Ne3x[0L-1T]e5>
2b.^ / [0L]Kx[+1L]e5
3w.^ Nd3#
```

Figure : Conversion of Plague's Notation to my notation.

Plague Notation:	My notation:
1. e3 Nf6 2. c3 d5 3. d4 c6 4. Nf3 Bf5 5w Ne5 5b Bf5xf2[0L-3T]% 3w Kxf2 -- 3b Ne4% -- 4w Ke1 -- 4b Nxc3 -- 5w Qf3 -- 5b e6 -- 6w g3 Qf3 6b Nc3xc1[0L]% 7w [-1]LBc1x[-1L-2T]c3 / 5b -- -- e6 6w -- -- g3 6b -- -- Qh4 7w -- / Qxc1[0L] 7b [-1L]Qd8h5[-1L-4T]% / / 4w g3 -- -- 00 4b Ne4% -- -- 00 5w Kg2 -- -- 00 5b e6 -- -- -- 6w Qf3 -- -- -- 6b Qf6 -- -- -- 7w [-2L]Qf3xf5[0L-2T] -- -- -- 5b -- -- -- -- e6 6w -- -- -- -- [+2]LQf5xf7[0L0T]% This softmate can't be defended. 6b -- -- -- [+1L]Qh4e1[-2L-3T]% This move is being played from the future T7b 5w Kxe1 -- -- -- 00 00 5b Qe4 -- -- -- -- -- 6w Qf3 -- -- -- -- -- 6b -- [-2L]Qh4e4[-2L-2T]# The king on -2LT5 is checkmated.	1. e3 Nf6 2. c3 d5 3. d4 c6 4. Nf3 Bf5 5. Ne5 <[0L]Bf5x[0L-3T]f2>% 6w. Kxf2 ^ 6b Ne4% ^ 7w Ke1 ^ 7b Nxc3 ^ 8w Qf3 ^ 8b e6 ^ 9w g3 Qf3 9b Nc3x[0L]c1% / 10w <[-1L]Bc1x[-1L-2T]c3> 10b ^ ^ e6 11w ^ ^ g3 11b ^ ^ Qh4 12w ^ / Qxc1[0L] 12b <[-1L]Qd8[-1L-4T]h5>% 13w g3 ^ ^ v 13b Ne4% ^ ^ v 13w Kg2 ^ ^ v 13b e6 ^ ^ ^ 14w Qf3 ^ ^ ^ 14b Qf6 ^ ^ ^ 15w [-2L]Qf3x[0L-2T]f5 ^ ^ ^ 15b ^ ^ ^ ^ e6 16w. ^ ^ ^ ^ <[+2L]Qf5x[0L0T]f7>% This softmate can't be defended. 16b.<[+1L]Qh4[-2L-3T]e1>% 17w Qf3 ^ ^ ^ ^ 17b ^ [-2L]Qh4[-2L-2T]e4# The king on -2LT5 is checkmated.

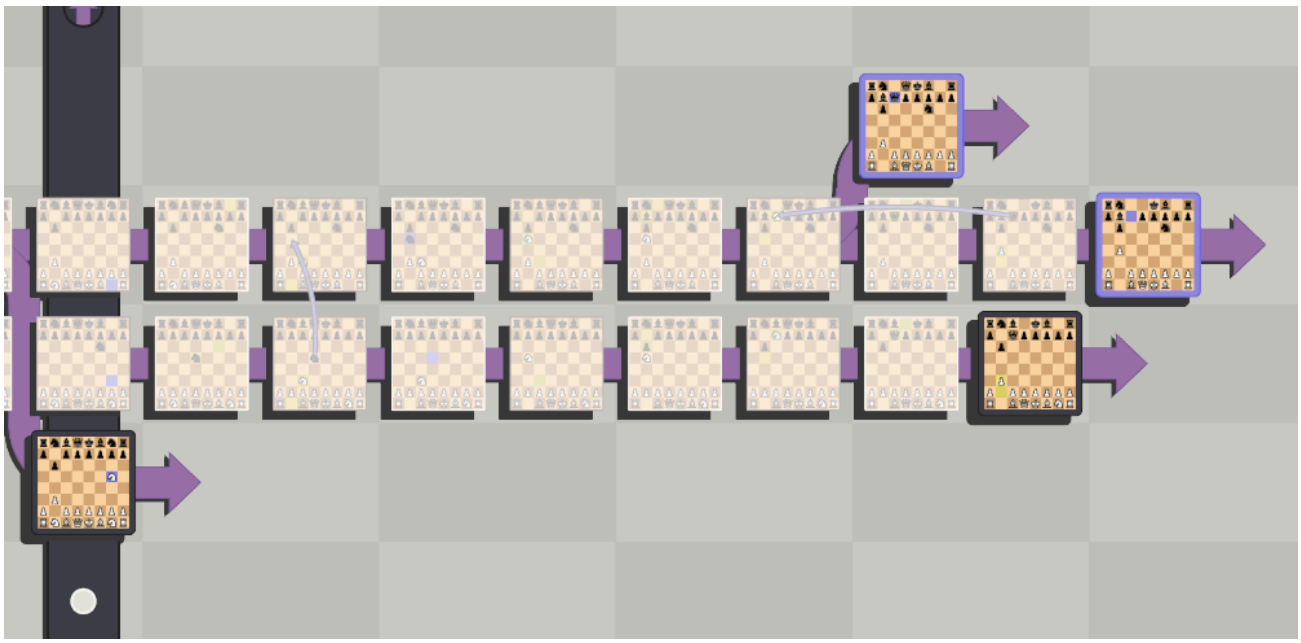
side note: using -- and 00 seems bad on readability. for instance 6w is somewhat hard to tell how many -- timelines there are. ^ seems a little better

standard game in public lobby:

```
1.Nf3 g5
2.d3 Nf6
3.Bxg5 Nc6
4.Nc4 Rg8
5.Qd2 e6
6.a3 Nd4
7.Nxd4 Rxg5
8.O-O-O Bh6
9.f4 Rc4
10.Kb1 Nh5
11w.<[0L]Qd2x[0LT8]g5>
11b.^ Ne4
12w.^ Nxe6%
12b.^ fxe6
13w.^ Qh5%
13b.^ Ke8[0L]f8
14w.^ Nxe4#
(The queen attacks the king in
the past)
```

1.Nf3 g5
2.d3 Nf6
3.Bxg5 Nc6
4.Nc4 Rg8
5.Qd2 e6
6.a3 Nd4
7.Nxd4 Rxg5
8.O-O-O Bh6
9.f4 Rc4
10.Kb1 Nh5
11w.<[0L]Qd2x[0LT8]g5>
11b.^ Ne4
12w.^ Nxe6%
12b.^ fxe6
13w.^ Qh5%
13b.^ Ke8[0L]f8
14w.^ Nxe4#
(The queen attacks the king in the past)

Edge case alert



I have fixed the edge case however this is still a consideration.

TLDR:

I. Intro.
   A. I'm trying to standardize notation, to read the paper you should know the basics of 5D chess and SAN
II. Terminology.
   A. Terms on the notation, look at the ones you are confused about.
III. Goals
   A. Different notations have different goals
   B. Human readability refers to visual clarity, how easy something is to read
   C. Ease of use refers to how easy a notation is to write - depends on simplicity of rules and verbosity.
   D. Machine readability is how easy a machine will be able to interpret the notation - not important to us.
   E. Clarity means lack of ambiguity -- there cannot be any ambiguity for any usable notation system.
IV. Other Notations
   A. Shad's Notation
      1. Made for his engine
      2. clean
      3. Not too many rules
      4. A little too verbose
      5. May not cover edge cases
      6. Some symbols seem unnecessary, but are only needed because of the way the notation works.
      7. what I compare other notations to.
      8. 8/10
   B. AN
      1. Least verbose notation I've seen.
      2. Lacks human readability, and a little bit complex
      3. May not cover edge cases
      4. 7.5/10
   C. Matrix Notation
      1. Made by a madman -- is a 2D notation on a spreadsheet
      2. Good visuals -- mimics those of 5Dchess
      3. Redundant information in 1d notation
      4. Need a spreadsheet/Screenshot to properly understand
      5. 7.5/10
   D. Hexicube's Notation
      1. A tweek of SAN
      2. Has some good examples
      3. Made to work for his specific game viewer.
      4. Uses placeholder of '-' for unused or unmovable timelines
      5. has the same pros/cons of AN
   E. AlexBays Notation

1. Made for his clone of 5D chess.
2. Usable as import/export into his engine/game
3. Low verbosity per move, but each move has its own turn prefix, and line.
4. Not super readable for humans, However, since the notation is meant for his program it doesn't matter much
5. 6/10

F. AverageHumans Notation
1. Very similar to RAN and AN.
2. was inspired by RAN and AN
3. Increases verbosity to denote origin square, even with spatial moves, and Layer is denoted(except for the origin timeline)
4. Low on human readability since coordinates are not broken up.
5. 7/10

G. Nidlatam's Notation
1. Honestly, I have no idea how to interpret this notation. It uses coordinates dissimilar to all other notations
2. It also uses terms like whited out which are confusing
3. Somehow you are able to notate the present
4. denotes color of piece, which is interesting
5. No full games are notated in this.
6. has its own notation for everything. even castling
7. 2/10 is very confusing but brings up unique ideas.

H. Kittlish's Notation
1. Very similar to this notation, built off of the same discussion.

V. Guidelines
A. Primary goal is to make the notation human readable rather than concise.
B. Secondary goal is conciseness.
C. There should only be one way to notate correctly.
D. Should be able to notate in something as simple as notepad.

VI. Considerations
A. Consider all edge cases, such as branching multiple times.

VII. Notation Theory
A. WIP -- very dry and doesn't really matter.

VIII. Rules
A. Just look at the rules -- they are meant to be brief.

IX. Examples
A. Examples of notation, in the future I may write some conversions etc.